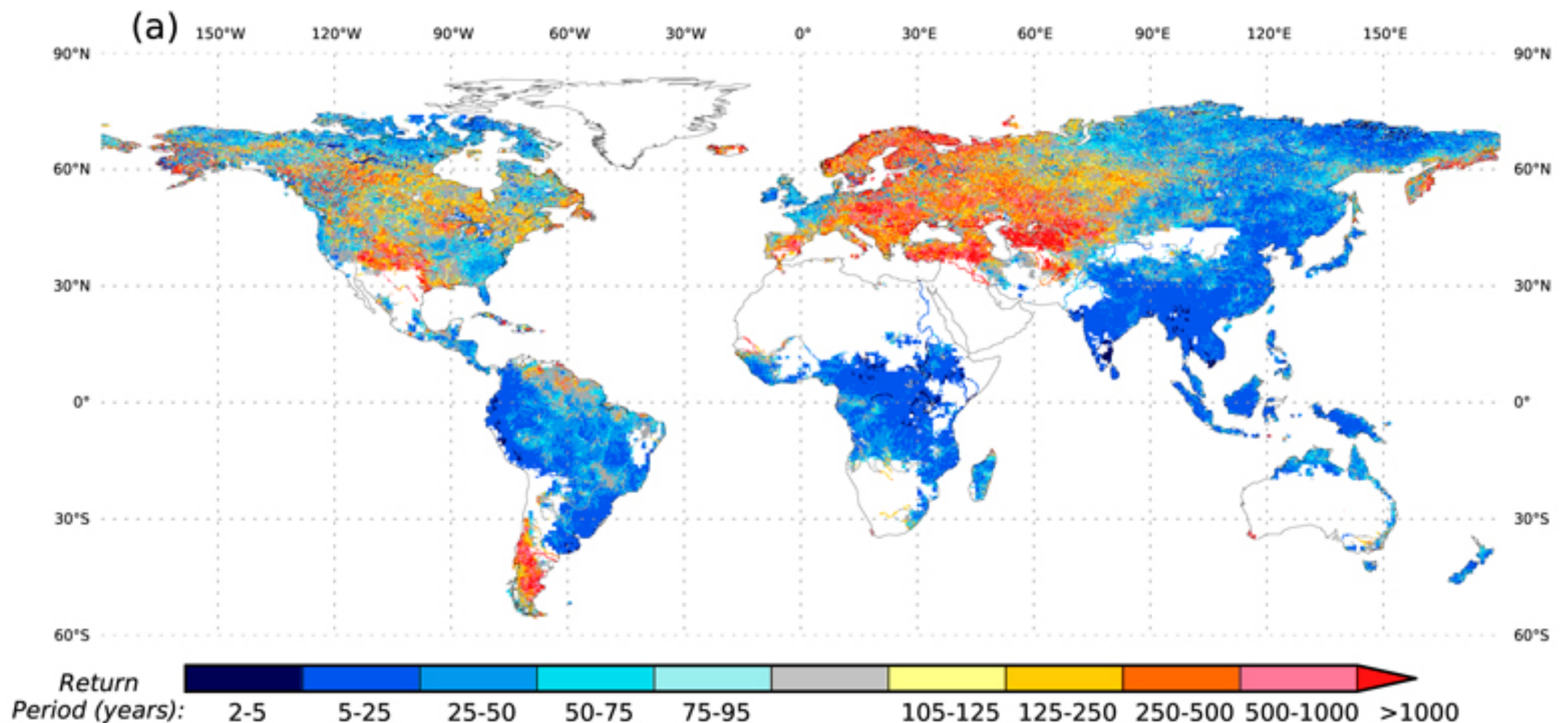


Floods and internal migration in the world

K. Kakinuma, M. Puma,
Y. Hirabayashi, S. Kanae

Extreme weather events

Climate changes may increase extreme weather events



Extreme events as the global risk

Global Risks Report

The 5 risks most likely to happen in the next 10 years

	rank
Extreme weather events	1
Natural disasters	2
Cyber attacks	3
Data fraud or theft	4
Failure of climate change mitigation & adaptation	5

Source: Executive Opinion Survey 2017, World Economic Forum

Challenges



Apr. 19. 2017



Impacts World 2017 HP

High public attentions... but few scientific evidences

(de Shrbinin et al. 2012; IPCC 2014)

Previous studies

Temperatures and migration in South Africa



Contents lists available at [ScienceDirect](#)

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

The influence of climate variability on internal migration flows
in South Africa

Mastrollio et al. (2016)

Floods and migration in Bangladesh

Unveiling hidden migration and mobility patterns in climate stressed
regions: A longitudinal study of six million anonymous mobile phone
users in Bangladesh

Lu et al. (2016) *Global Environmental Change*



Few studies focus on the **global scale**

Objective

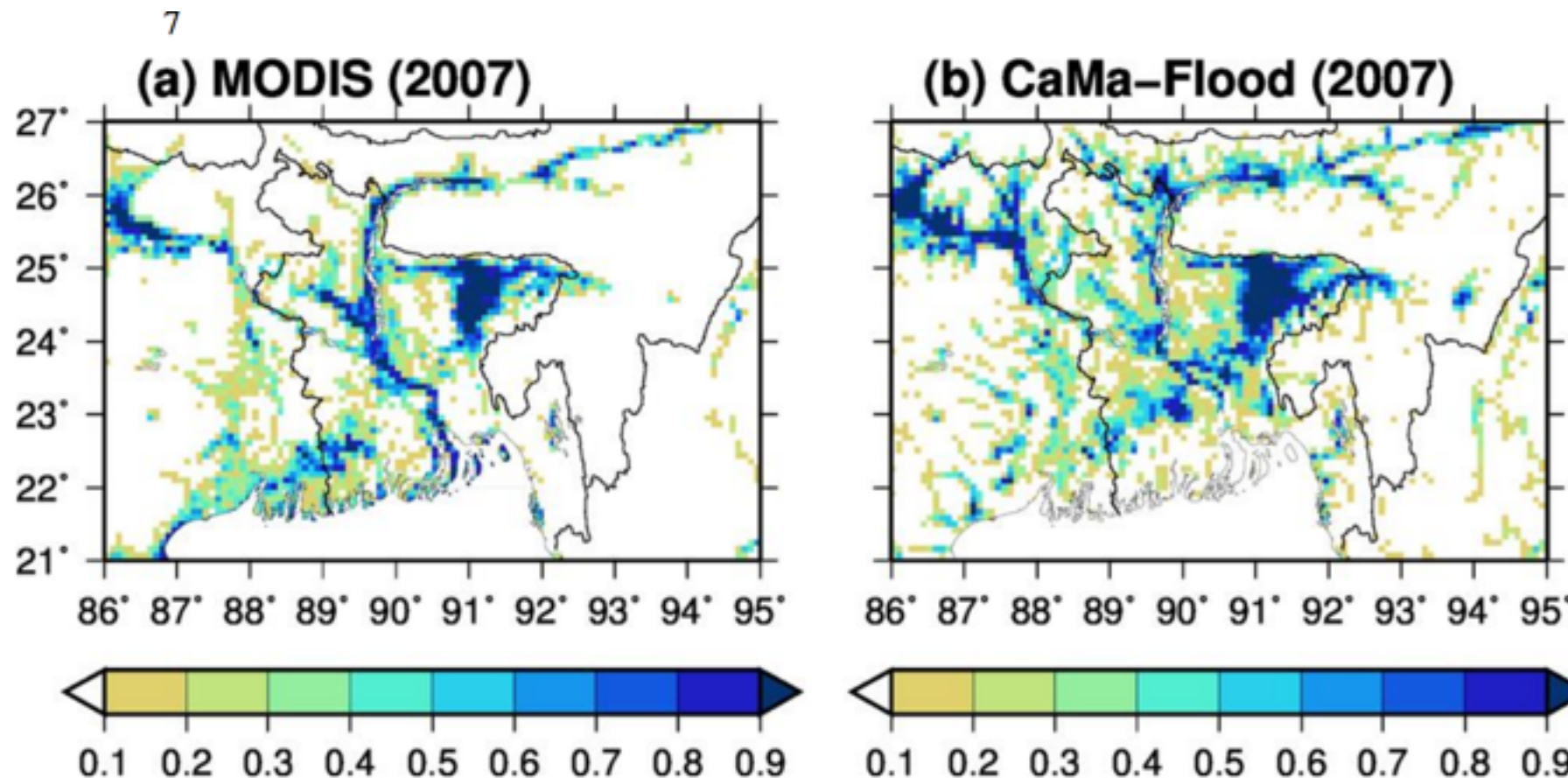
The relationship among floods, internal migration and economic conditions across the globe

Flooded areas

Global river and inundation model:

the Catchment-based Macro-scale Floodplain model (CaMa-Flood)
(Yamazaki et al. 2011)

- Resolution: $5' \times 5'$ (approximately 10 km \times 10 km at the equator)
- Term: 1960-2013
- Anomaly of flood areas at each country



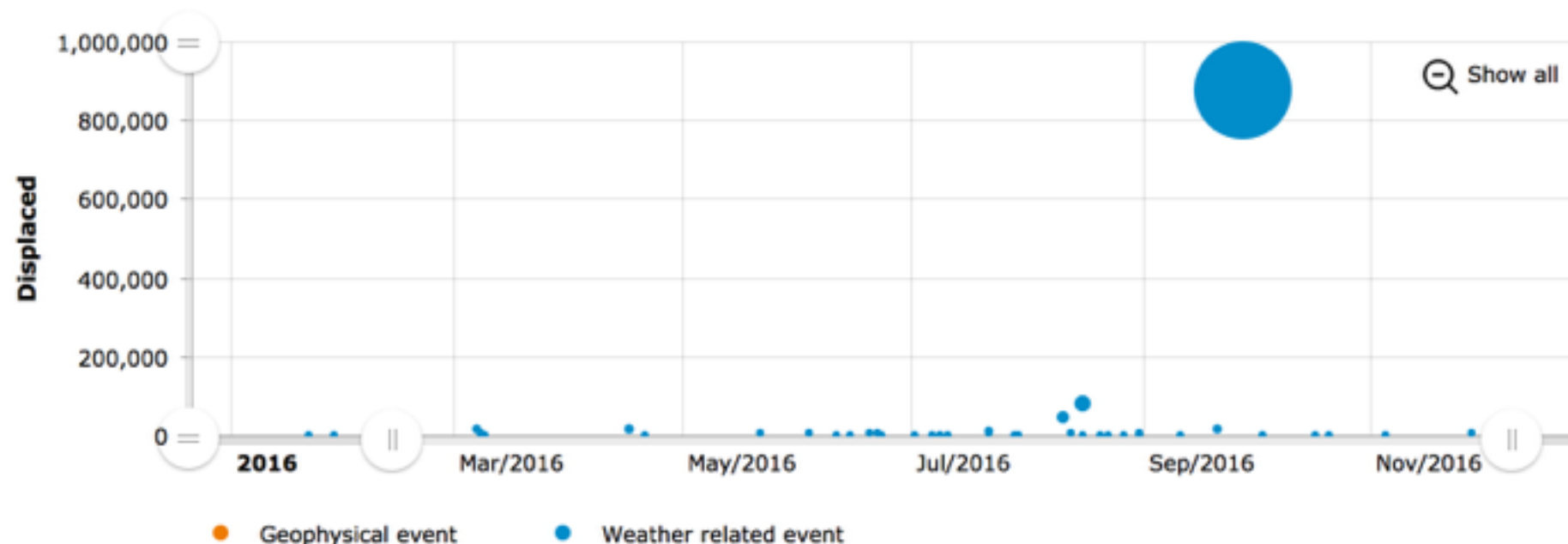
Tanoue et al. (2016)

Population migration

IDMC Global Report on Internal Displacement 2017 Disaster Dataset

- Term: 2008-2016
- Event basis
- Data sources: national government authorities, UN agencies and other international organizations, civil society organizations, news media etc.
- Internal migration that caused by “Flood”, “Storm”
- Rate of population migration to total population (World bank 2017)

Events timeline

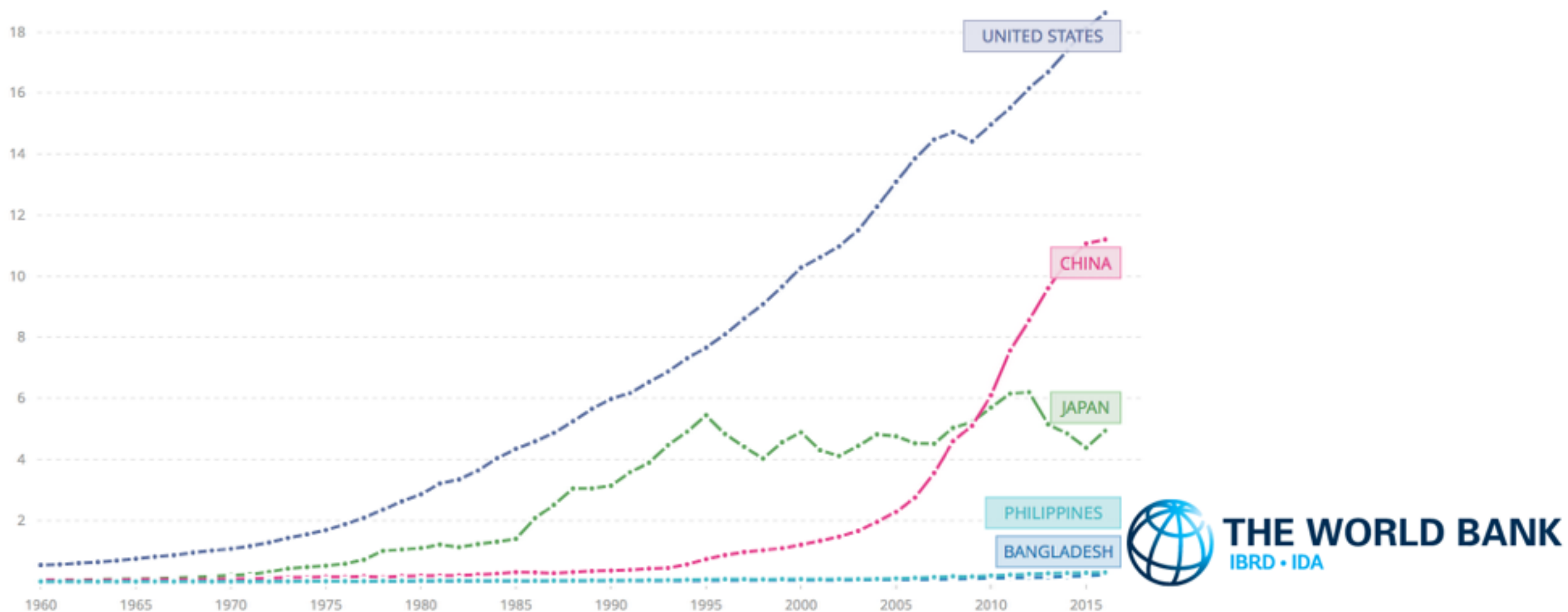


<http://www.internal-displacement.org/countries/>

Economic condition

World Bank (2017)

- Gross Domestic Production
- Term: 1960-2016
- Each country



Statistical Analysis

Generalized linear mixed model (GLMM)

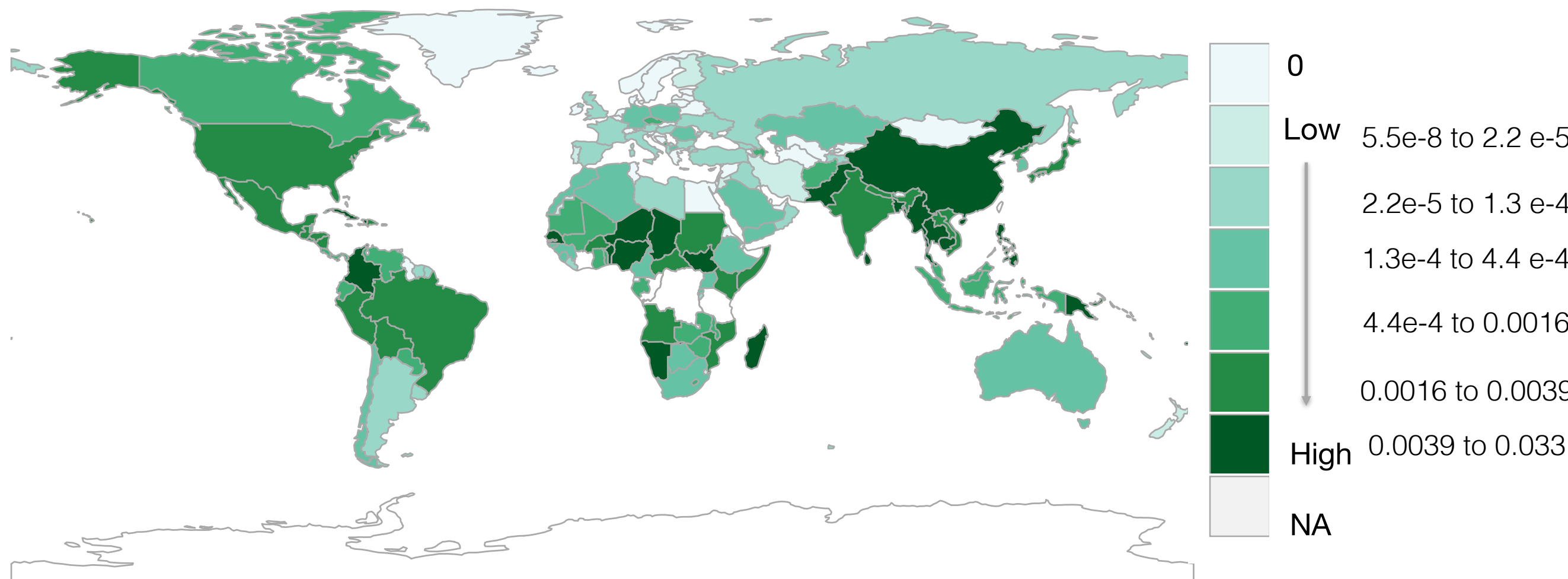
Migration to total population $\sim \beta_0 + \beta_1 * \text{GDP} + \beta_2 * \text{anomaly of flooded areas} + \beta_3 * \text{GDP} * \text{anomaly of flooded areas} + \phi_j$

β_i is coefficient of explanatory variables

ϕ_j : Random effect, Year

Floods & Internal migration

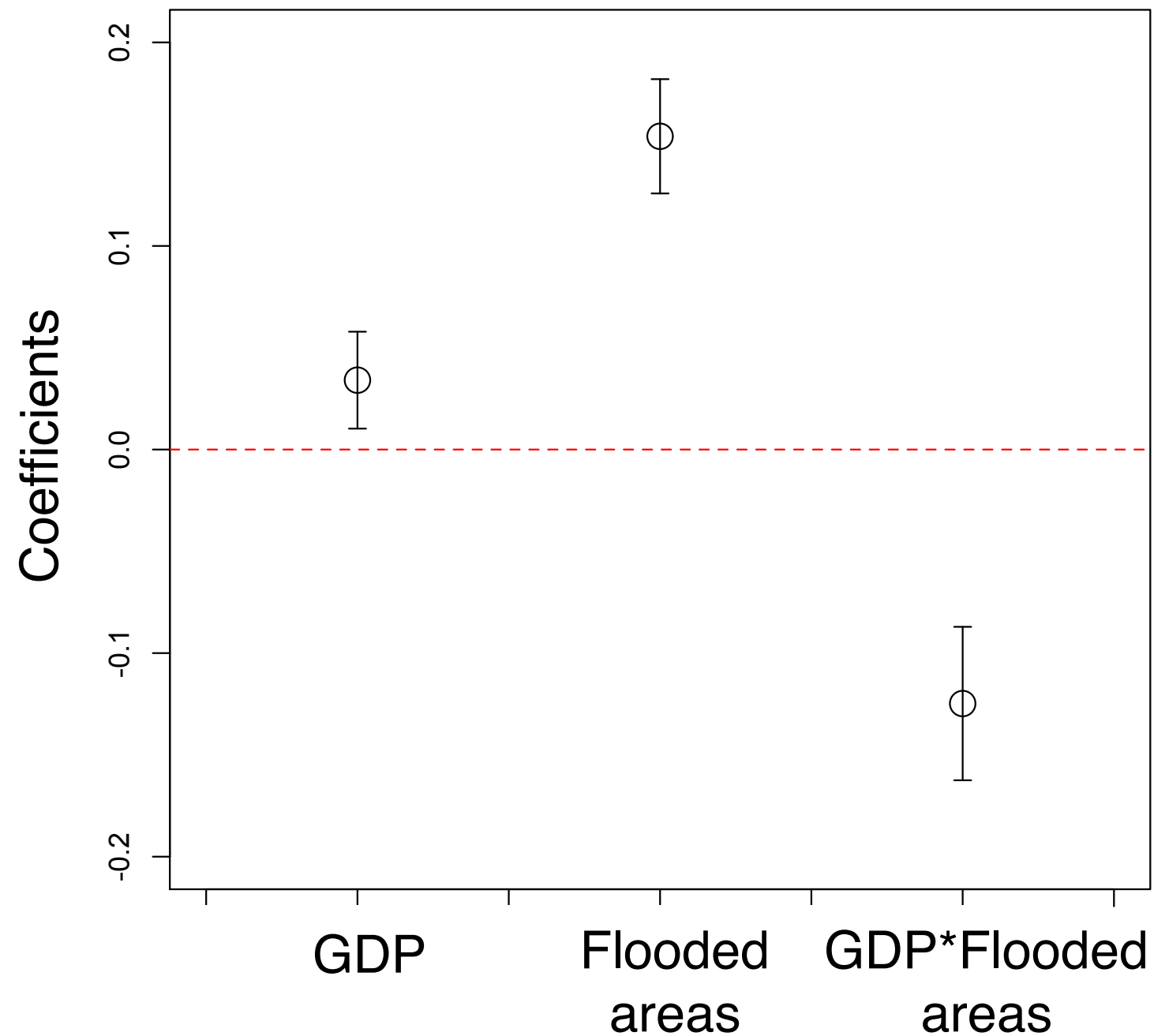
Average rates of internal migration that related with flood
2008-2016



Data from IDMC

Countries in **African, South, Southeast Asian, the northern Andes** had high rate of internal migration

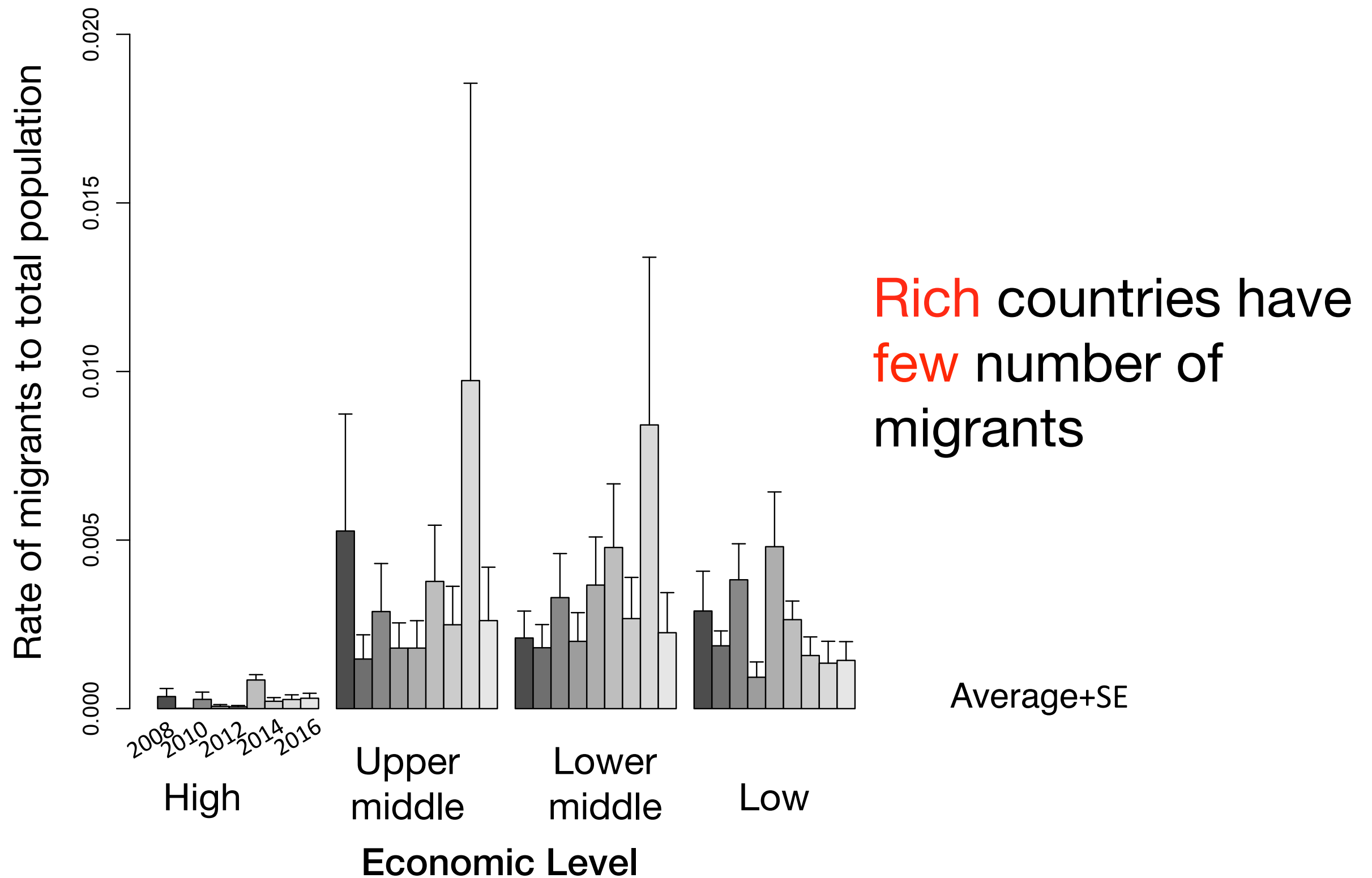
Result of GLMM



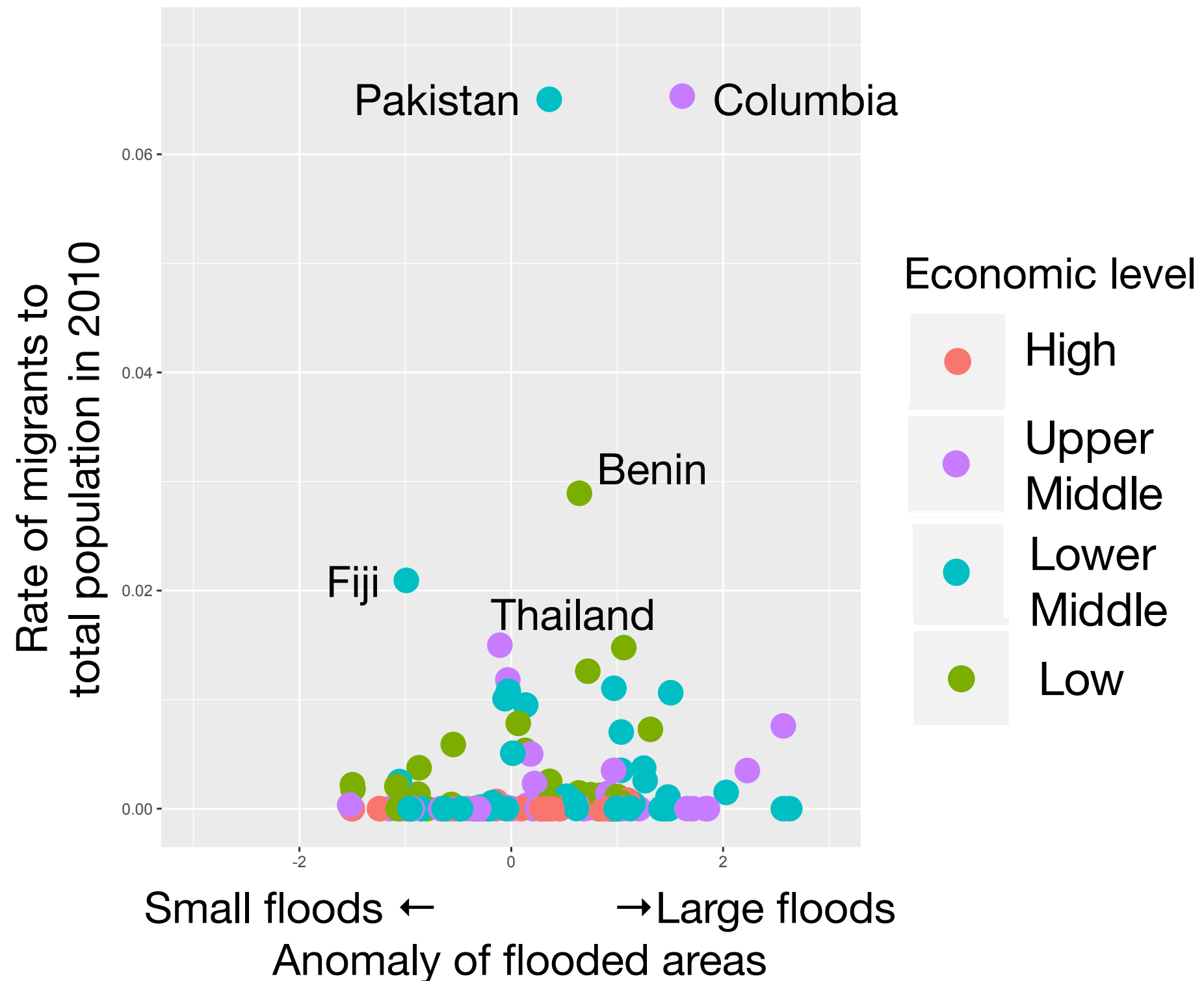
- Anomaly of flooded area (+)
- Interaction of flooded areas and GDP (-)

Bar means standard error

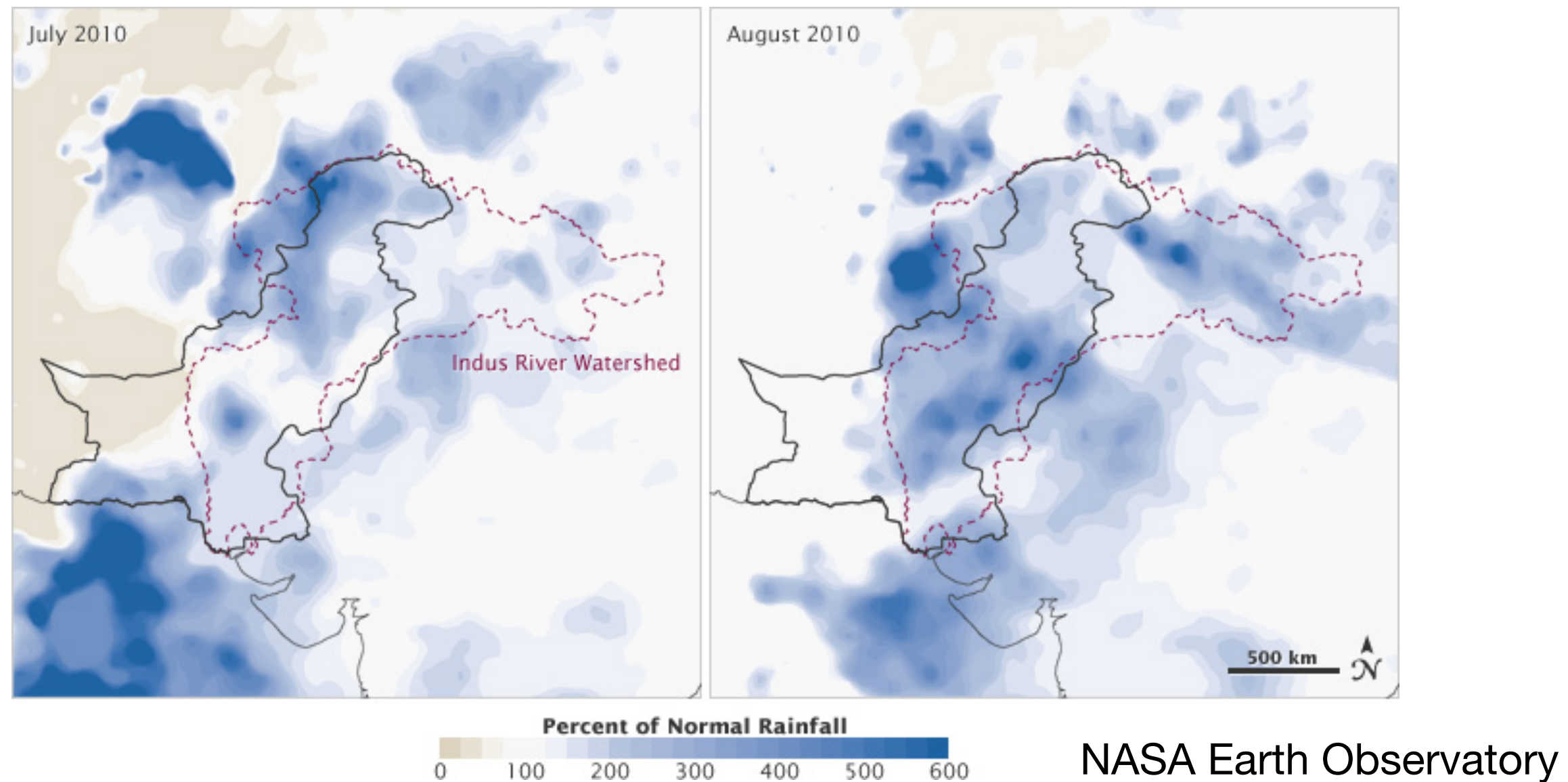
Economic condition & Migration



Flooded areas & Migration



Flood in Pakistan, 2010



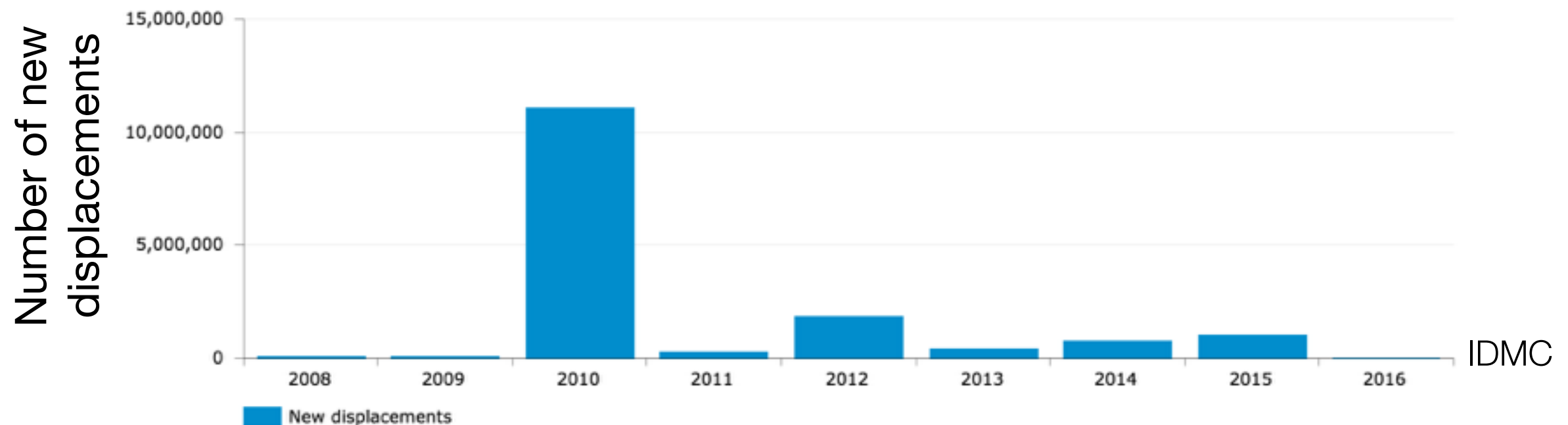
The **heaviest** rainfall events from the previous

- July was up **772%** from normal
- August rainfall was up **1483%**

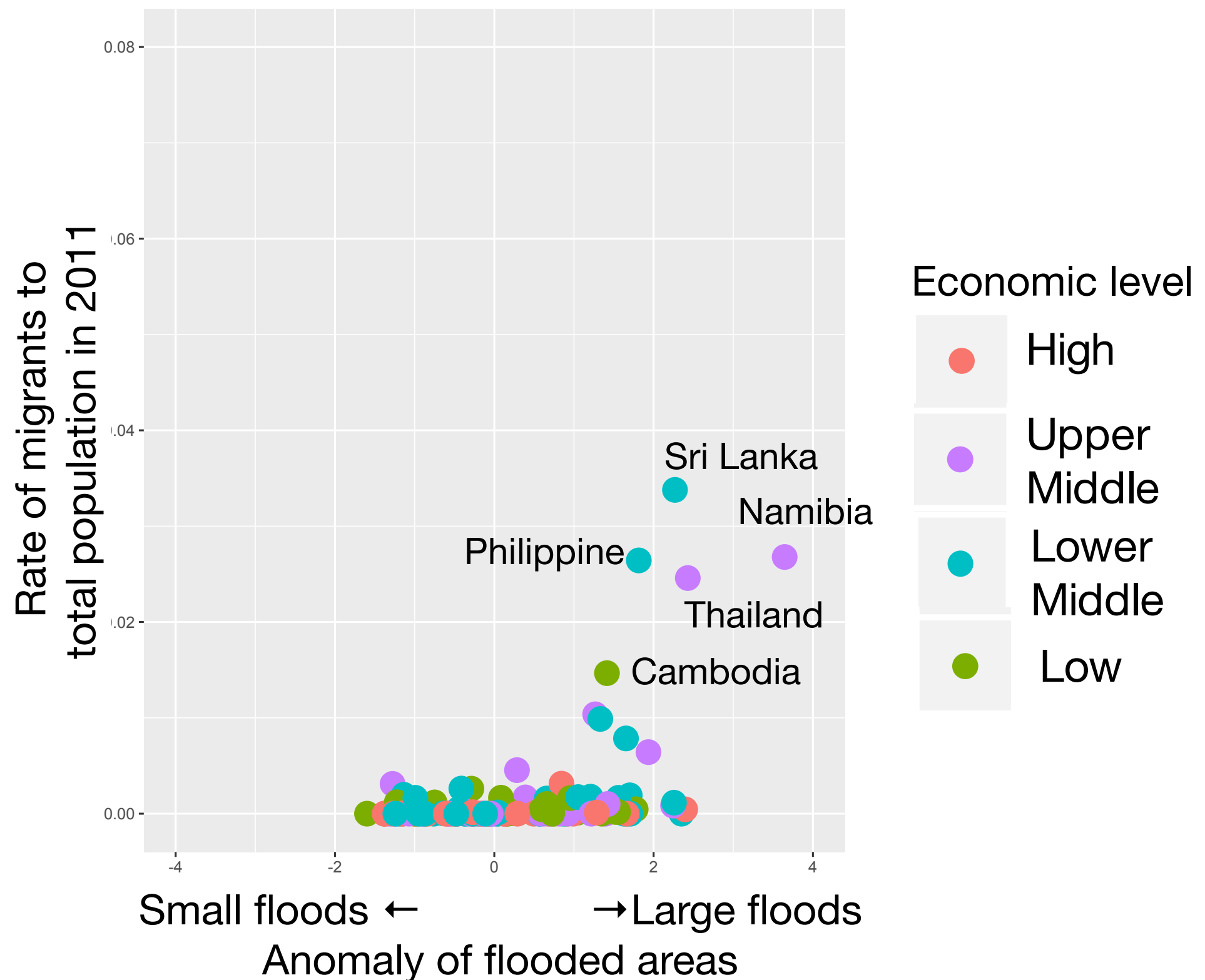
Flood in Pakistan, 2010

Huge impact on society

- 14-20 million people affected
- 1.1 million homes were damaged (Kirsch et al. 2012)

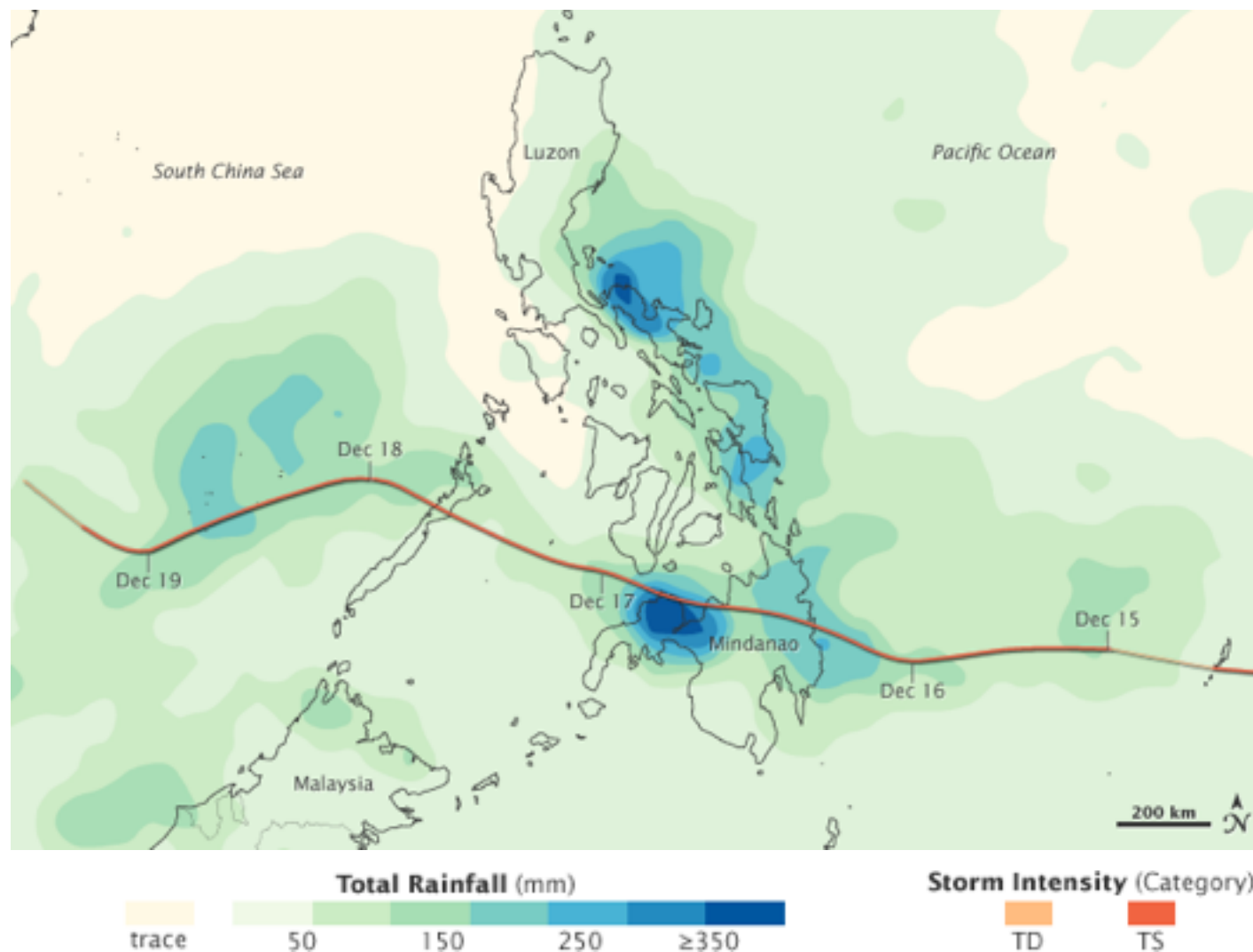


Flooded areas & Migration



Floods in Philippine, 2011

Tropical storm “Washi”

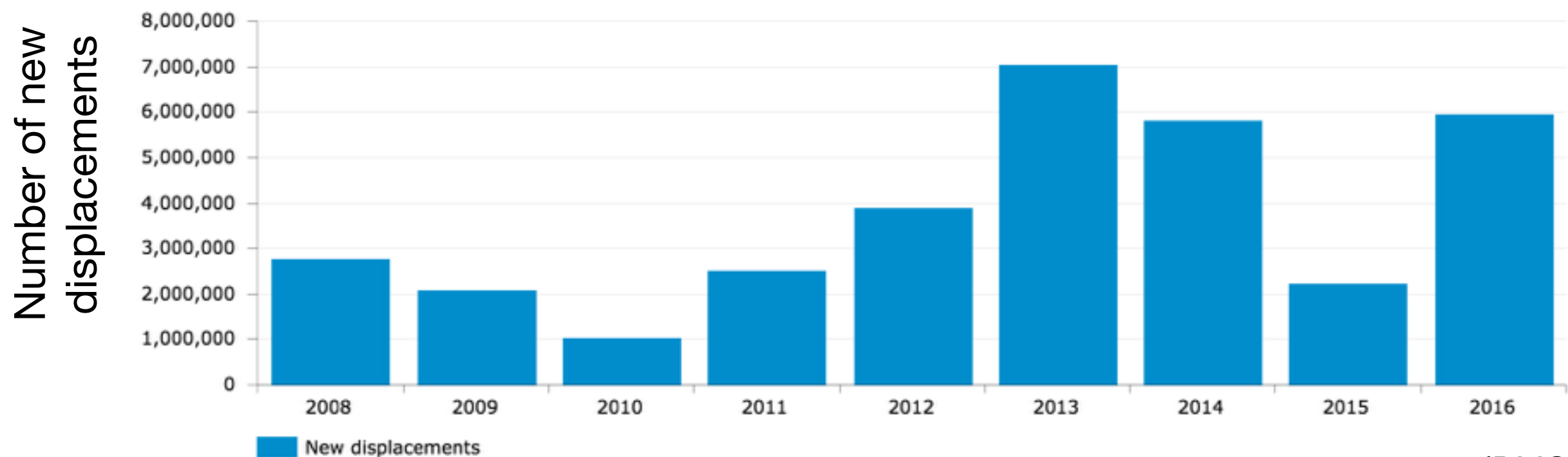


- 0.6 million people affected
- 28,000 homes were damaged

NASA Earth Observatory

Precipitation during Dec.15-19

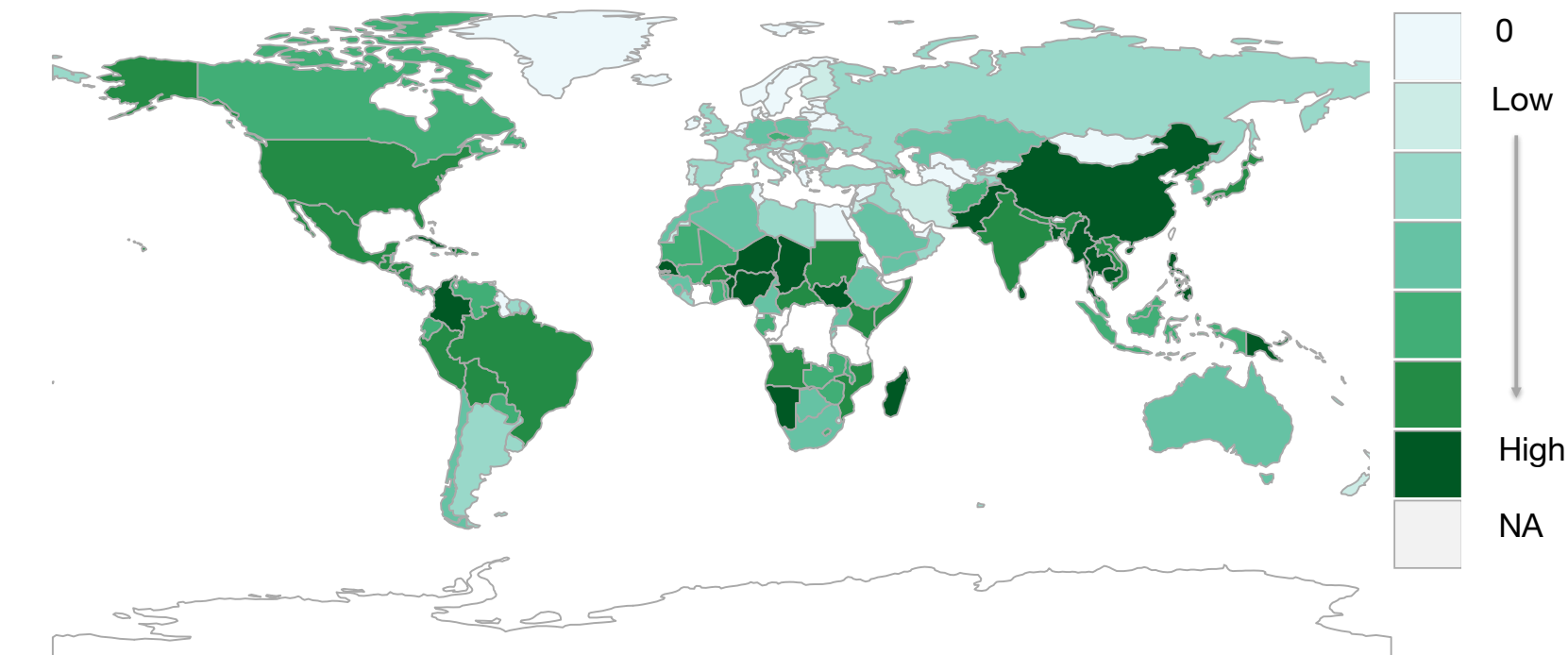
Floods in Philippine, 2011



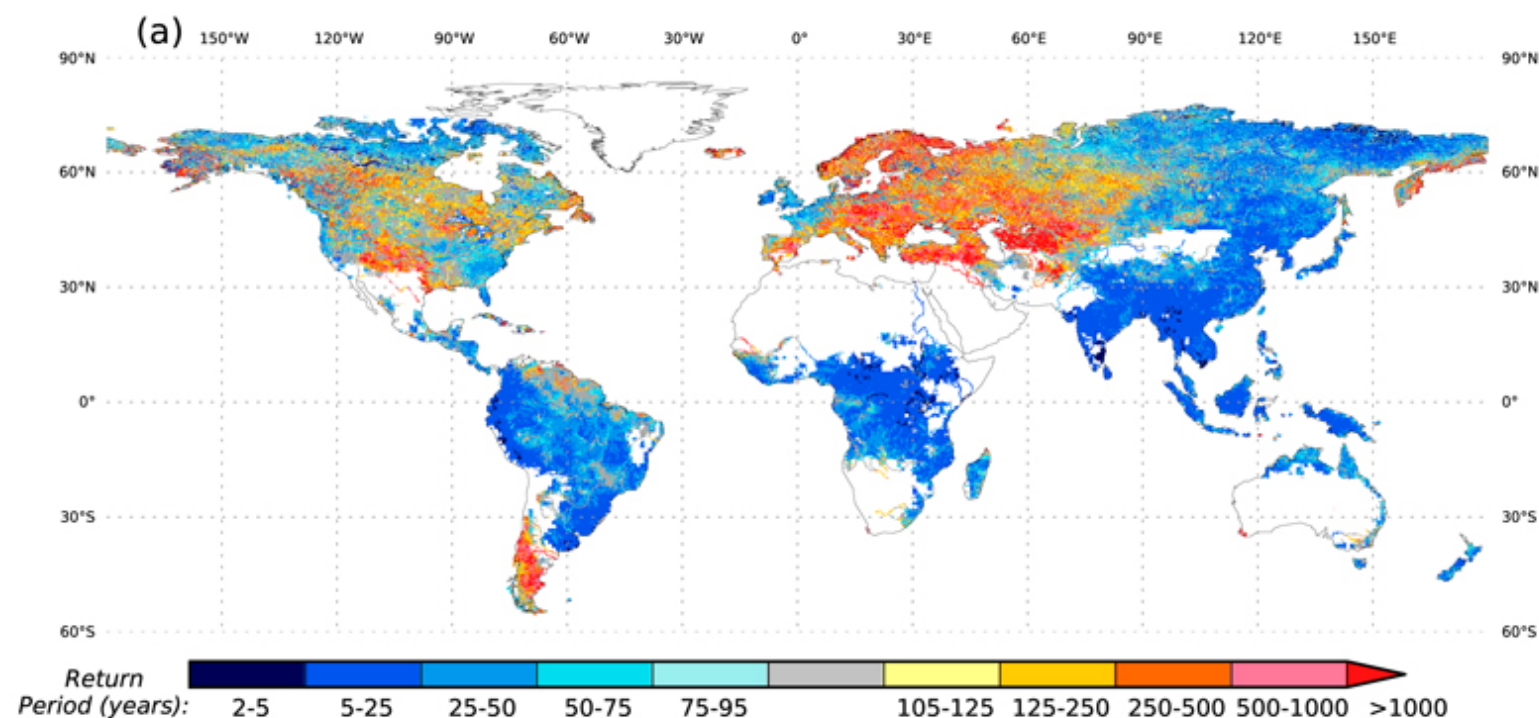
IDMC

Philippine has large number of disaster-related migrants for
several years

Future flood projection



Flood frequency are projected to increase in some of these countries



Limitations & Future tasks

Definition of “a large flood”

- We consider only “flooded areas”
- We’ll try to consider “flood affected population”

What kind of a flood is matter?

- Are there any threshold (**a critical point**) of flooded areas?
- Are there any other triggers to human migration?

Summary

Although the public attention is increasing, there are few knowledge about the migration that associated with **extreme weather events** across the globe

- **Internal migration** that caused by flood were mainly occurred in African, South, Southeast Asian, the northern Andes regions
- Flooded areas itself may relate with internal migration
- **Interaction** of **flooded areas** and **economic condition** may affect population migration

Conclusion

Floods may have critical impacts on population migration especially in middle and low income countries